Telesaving and ISDN

Making the most of ISDN with DIGITAL RouteAbout products.

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1 Executive Summary

More and more branch office networks are using the now widely available Integrated Services Digital Network (ISDN). The main attractions are the promises of substantial performance improvements over similarly priced analogue services, of a cheaper alternative to high-priced leased-line or other data services (see ISDN Tariffs), and of greater service flexibility and accessibility. Key to the attraction of ISDN is the ability to set up and take down links so quickly that routing circuits only need to be brought up when data is sent. This makes ISDN as flexible as the existing analogue telephone network but with superior performance and capacity. Users typically pay an initial connection charge, a monthly rental and a usage charge based on connect time - just as with a telephone. As with a telephone network, there is the opportunity to minimize the costs by judicious use of the time you are connected. But more importantly, injudicious use of the network can incur heavy costs and wipe out the benefits anticipated.

To help ISDN users, DIGITAL has designed a set of features collectively known as Telesaving for its RouteAbout family of wide area access and central office routers. This whitepaper describes these features and how they can be used to help users minimize their costs and maximize their available bandwidth when using ISDN services. It also provides basic information about ISDN technology and tariffs that users should be aware of when contemplating moving to ISDN.

2 Telesaving

The definition of Telesaving for this document is: *"Reducing the cost of WAN links by optimizing available bandwidth and sensitivity to use-based tariffs"*. The goal of Telesaving is to maximize the available bandwidth while minimizing the costs.

In regions that have 'use-based' ISDN tariffs, it is very important to tune the Telesaving features optimally. Not achieving this may result in running costs far in excess of alternative data services.

The Telesaving features implemented or planned by DIGITAL can be divided into the following groups :

Connection Management - making best use of the tariff structures for connections and services
Data Management - getting the maximum out of the available bandwidth and ensuring that non-essential traffic does not eat it up
Working Practices - changing the way work is done to save connection time
Installation and Service Options - selecting cost effective installation and service options

2.1 *Connection Management*

With the rapid call establishment available with ISDN links, it is possible to disconnect the ISDN call during periods of inactivity without causing a noticeable disruption of service. The ISDN connection is offered to the routing and data-forwarding objects in the router as 'Available' even when an ISDN call is not actually 'up'. When there is data to send, the call is rapidly reconnected. In regions that have a 'use-based' tariff, e.g. charges are made for each unit of seconds or minutes connected time, significant savings can be made by careful setting of the features described in this section.

To give complete control over the cost

incurred on ISDN links, Budget Controls are used that allow monitoring and notification of budget-related events (e.g. rate at which budget is being used). With Budget Control functions, it is possible to ensure that other Telesaving techniques are working.

2.1.1 Bandwidth on Demand (BoD)

With ISDN's rapid connection capabilities, it is possible to leave connections idle (i.e. not actually connected) until data is delivered to the router for forwarding. An 'idle timer' is used to detect when the connection can be removed again. In additional to this, if the data load reaches a defined threshold, it is possible to add more bandwidth by making additional ISDN calls to the target site and aggregating the channels together. Bandwidth Aggregation is achieved by using Multilink PPP to 'bundle' ISDN channels into one logical channel between the same pair of routers. A third use of BoD is to provide fail-over or backup bandwidth when a primary link has failed (See WAN Reroute/Restoral below). The following features are implemented to manage the Bandwidth on Demand functions:

- 'BoD Threshold' - % load of available bandwidth used before adding more capacity.
- 'Sample Timer' - Controls how frequently the load is monitored
- 'BoD add link persistence' and 'BoD delete link persistence' - Additional timers that allow sensitivity to peaks and troughs to be controlled.
- Multiple Base Links - Specify the number of dial-links that should be connected when data transfer is detected.
- Maximum Links - Specify how many links can be added to a particular bundle

2.1.2 Bandwidth Aggregation Control

Although being able to make use of additional bandwidth is convenient, it is also costly. For some links, it may be desirable to restrict the use of additional bandwidth to certain times of the week, e.g. end-of-business data loading to a central site, or to take advantage of cheaper call charges at weekends. The following controls are implemented to manage the Bandwidth Aggregation Control functions:

- Save use of additional bandwidth for 'busy-hour', e.g. end-of-day processing.
- Time-Of-Week Profile to control the extent of additional bandwidth usage.
- Control Options - Call-Direction sensitivity and allow/disallow status.

2.1.3 Idle Timer

To enable ISDN calls to be disconnected, the data activity on the link is monitored. If a particular link is 'idle' for 'Idle Timer' seconds, the call is disconnected allowing connection-time savings. This timer should be tuned to typical application used over the link. When working with Multilink PPP, this timer is used once a channel in the bundle is marked as 'surplus to requirements'.

2.1.4 Initial Minimum Call Timer (IMCT)

Many ISDN service providers impose a Minimum Call Charge and the amount of connection time this charge pays for may vary during the week - e.g. the charge may

cover a 30-second call during working-days and 90-seconds during weekends. Since this initial part of a call is pre-paid, it is cost-effective to insure that calls are not disconnected prematurely. With such a tariff policy, it is very expensive to make back-to-back minimum duration calls. The following features are implemented for effective use of the IMCT function:

- If the service provider has a 'Minimum Charge' for each call, use this timer to prevent premature disconnection.
- Time Of Week variance via Tariff Profiles to match tariff 'zones'
- Interworking with Bandwidth On Demand timers and controls.
- Interworking with Idle Timer.

2.1.5 Call Blocking

In some network environments, it may be necessary to limit the usage of the ISDN line to control when and how it is used. For instance, if the ISDN Tariff has peak times when charges are higher, it may be desirable to prevent automatic connection during these periods. This feature is used to control when calls are 'allowed' and operates for both inbound and outbound calls. The following features are implemented to manage the Call Blocking function:

- Action - Block Call, Log SNMP Trap, Log console event
- By Time-Of-Week Profile
- Force active calls to be disconnected at certain times or not
- Call Direction options - Incoming/Outgoing/Both

2.1.6 Calling Line Identifier (CLID)

Most ISDN services provide, usually as a chargeable option, Calling Line Identifier or CLID. When an ISDN call is placed, the CLID is passed using the D-channel to the receiving end of the call. The receiving end can then decide whether to accept or reject the call based on matching the CLID against a list of valid identifiers. Since this decision can be made before accepting the call, no call charges are incurred for rejected calls. Thus saving call charges at either end of the call. The CLID can also be useful in implementing a call-back feature (see below).

2.1.7 Budget Control

A concern when installing networks that will use ISDN links is the potential for incurring very high ISDN charges due to unexpectedly high usage, poor tuning of the Telesaving features of the Routers, or poor working practices. This feature allows network managers to set budgets and stay informed on the rate of spending making it possible to take early action to fix ISDN connection problems. It has controls which allow you to:

- Specify Budget in Charge Units/Time Connected
- Refresh the budget by Time Of Year e.g. at the start of a new budgeting period
- Specify percentage of budget to allocate in different tariff call bands
- Specify action(s) when a percentage of the threshold is used e.g. log event/SNMP Trap, or none
- Specify action(s) when all the budget

is used e.g. log event/SNMP Trap, Block Charged calls/All Calls, Apply overdraft, or none.

2.1.8 Call-Back

Some ISDN service providers will offer discounts for high usage of ISDN links. It is the Calling-end of an ISDN link that is charged for the connection, so using Call-Back, it is possible to centralize the call charges and achieve the maximum discount. Also, for international ISDN, it may be cheaper to make calls from country 'A' than from country 'B' so calls from country 'B' are configured to request Call Back when calling 'A'. The Call-Back function allows the following kinds of control environment to be established:

- Centralize billing in order to take advantage of bulk-usage discounts
- Make use of cheaper tariffs in remote regions (e.g. International calls from Country A to Country B may be cheaper than calls from Country B to A)
- Time Of Week variance (to allow for different tariff zones in different regions)
- Using Calling Line Identifier (CLID) facility to implement 'one-call' call-back.
- CLID facility is usually a chargeable item, so activate on central only to save costs

2.1.9 WAN Reroute/Restoral

ISDN links provide a cost effective way of providing resilience in a network since a router with an ISDN link can connect to any other router in the network equipped with ISDN. This approach makes failure-proof, fully-meshed networks possible at a fraction of the price of using Leased Lines or Frame Relay PVCs. WAN Reroute secondary links are typically used to fail-over to a different Router than that connected to using the Primary Link. WAN Restoral is used as fail-over to the same router as connected to by the Primary link.

2.1.10 PPP Echo Suppression

Some implementations of PPP (including the DIGITAL one) generate ECHO packets to monitor the link quality. To ensure that these ECHO packets do not keep the link up when no data is being sent, the ECHO packets should not be counted as real data or contribute to resetting the Idle Timer.

2.2 *Data Management*

Bandwidth Optimization is important for any expensive WAN resource (leased-line, Frame Relay and ISDN), but is particularly important to ISDN links since tools such as data compression mean that data can be sent faster and hence there may be longer idle periods and more opportunities to disconnect the call to save money. There are two parts to Data Management that are relevant to Telesaving :

- Compressing data to increase the effective bandwidth
- Reducing the background noise associated with "chatty" protocols

2.2.1 Compression

Compression can greatly reduces file transfer times thus allowing for more idle time and cost saving. It also can mean that there is more available bandwidth for

incompressible data

The ability to compress data varies greatly with the type of data being transferred. The raw data rate (with PPP and TCP/IP overhead taken into account, but not bit stuffing) over a single B-channel is approximately 7.7 KBytes per second. Here are some typical ratios for 'STAC V5' compression for various file types :

.doc	.zip	.pdf	.ps	.txt	.xls	.html
11 KB/s (1.7:1)	7 KB/s (1:1)	8 KB/s (1:1)	25 KB/s (4.3:1)	14 KB/s (2.5:1)	13 KB/s (2.5:1)	15 KB/s (2.0:1)

Table 1: Compression ratios

As a general rule, pre-compressing data will increase throughput. In some cases (such as converting .ps to .pdf format), transfer time can increase. Note that for efficiently compressed data, the compression algorithm can actually increase the file size, and for this reason, the implementation can detect this and disable compression while continuing to monitor the data for compressibility. The PPP Compression Control Protocol (CCP) is used for managing the compression across the ISDN link

2.2.2 TCP/IP Filtering

The common TCP/IP routing protocols in use were not designed with ISDN Telesaving in mind since they send frequent updates which could keep an otherwise idle ISDN link permanently open. Generally, TCP/IP generates less broadcast message than protocols such as Novell Netware and AppleTalk as it was designed with the wide area in mind as the network protocol for the US Department of Defense networks. There are certain features, however, which should be given attention when considering Telesaving.

2.2.2.1 Triggered RIP

A proposal to the IETF known as 'Triggered RIP' removes the need for broadcasting routing information by using an acknowledged route exchange and only sending news of route changes as they happen. The only effective alternative to Triggered RIP currently is Static Routes, but they may require significant manual configuration, and will reduce the possibilities for efficient fail-over and re-routing. The main features of the implementation are that:

- Routes are sent just once and are acknowledged.
- There are no periodic broadcasts.
- Addition of a 'Good-News' extension to the RFC that prevents dial-circuit costs due to route 'bounces'. This extension is compatible with the RFC and will "piggyback" bad news about existing routes only on a data flow.

2.2.2.2 Static IP Routes

With static routes, links are manually configured into the router instead of being

dynamically learnt using routing protocol exchange. This means that the periodic routing updates are not sent over the ISDN link requiring a call to be established. Static routes are most useful in simple network configurations where there is little change in the topology. For example, 'Star' networks where all branch offices are linked to a single router at the central site are ideal candidates for static routes as it is unlikely for the central site to move or change its address.

2.2.2.3 TCP Keepalive Spoofing

Many TCP/IP implementations generate 'Keepalive' polls on connected TCP sessions. If a TCP connection remains connected for long periods of time without actually being used, these polls can keep ISDN links busy for no real purpose. This feature allows routers to 'Spoof' the acknowledgment being requested by the Keepalive Polls and thus not actually forward the Keepalive poll over the ISDN link. the "Call sensitivity" is an added feature which allows polls through if call is active for other data.

2.2.2.4 IP Access Control

The IP Access control feature allows you to filter IP packets by source, destination, message-type or port. This is particularly useful for bridged links where the normal routing mechanisms do not apply.

2.2.2.5 PIM tuning

There are a number of timers that can be increased to reduce the number of protocol messages exchanged in a Multicast network :

- Query interval
- Join interval
- RP-reachability interval

2.2.3 IPX Filtering

Novell's Netware protocols provide plug-and-play operation for clients and servers connected on a LAN. Netware clients and servers use "keepalive" messages which they broadcast on the LAN so that the clients and servers can keep track of connections. When connected over an ISDN link, these "keepalive" messages can cause the link to be brought up and unnecessary costs incurred. The Netware routing protocol and service advertisements can also generate overhead traffic and need to be controlled by filtering or timer adjustment.

2.2.3.1 IPX Spoofing

IPX has a number of broadcast messages that can cause 'noise' on WAN links. The most frequent of these is the "Keepalive" messages sent by the Server to Clients that have logged-on.

The following controls are used to manage the IPX spoofing function:

- Watchdog timer server-side spoofing
- Client-side keepalive spoofing

2.2.3.2 Route/Service Filtering

To reduce the number of Networks and Services advertised over an ISDN link, unimportant Networks/Services advertised using IPX RIP/SAP messages can be filtered out.

2.2.3.3 Timers for IPX RIP/SAP broadcasts

Where service broadcasts are required over an ISDN link, the frequency of IPX RIP/SAP broadcasts can be increased to minimize the extra calls that may occur.

2.2.3.4 IPX Access Control

As an added control, IPX data can be filtered-out based on Source/Destination Network, Host or Socket. This allows any traffic which cannot be controlled by some of the other Telesaving methods to be explicitly excluded.

2.2.3.5 NETBIOS over IPX filtering

NETBIOS is used extensively in Microsoft Windows95 environments where it is replacing the older NETBEUI protocol for LAN workgroups. NETBIOS over IPX uses broadcasts to communicate between clients and servers. On bridged links, NETBIOS traffic needs to be filtered to prevent unnecessary link activation.

2.2.4 AppleTalk filtering

AppleTalk is similar to Netware in the was services and routes are advertised. These filters allows AppleTalk messages to be blocked by Zone and Network.

2.2.5 Timer Server

If you need to use a remote Time Server over an ISDN link, increasing the Synchronization timer is advisable.

2.3 *Working Practices*

The way in which network users work should be examined to help reduce ISDN costs:

- Bulk data transfer when tariffs are cheaper - (e.g. mass data transfer at weekends).
- Power-down during non-working hours. If routers are turned-off, they can't make calls!
- Local editing - edit locally, then copy.
- Bulk mail copy and reply - use mail processing application that allow bulk copy of unread and reply mail.
- Browser Cache (e.g. Netscape) - Increasing the Cache reducing the network cost of retrieving a page.
- Terminal Sessions - avoid 'broadcast' or system-manager notification messages that may cause traffic on networked terminal sessions - e.g. rlogin TCP connections.
- For IPX networks, if possible install a local 'Preferred IPX Server'.
- Disable BOOTP forwarding if acceptable to do so.
- NETBIOS Keepalives - reduce the frequency or use TCP Keepalives instead and enable TCP Keepalive spoofing in the Routers.
- 'Proactive' service browser applications (e.g. Microsoft Domain browser). Disable or reduce the frequency of proactive, or back-ground activities,
- TCP send/receive window increase can improve WAN throughput.

- Disconnect from Network Resources (shared disks, printers, TCP sessions) when not in use.
- FTP disconnection timers. Increase these to prevent session terminating before required.
- Compress large files before copying over an ISDN link (e.g. using ZIP tools).

2.4 *Installation and Service Options*

There will normally be the following parts to the ISDN Tariffs and all aspects should be considered to help cost reduce each installation :

- Installation of the local loop - some services are offered in various 'flavors' which all have different installation costs. For example, a 'Low Use' connection may carry a higher installation charge than a 'High Use' connection.
- Installation of the NT1 - In some regions (e.g. USA), the NT1 is purchased/rented from a supplier of the customers choosing.
- Monthly Rental - Monthly rental can vary, e.g. Primary Rate ISDN may carry a different rental per B-channel than Basic Rate.
- Facilities requested (e.g. CLID) - Calling Line Identifier (CLID) is particularly useful at a central site (to be used for Call Back), but will incur a rental charge. Reserve this feature for the Central Sites if possible.
- Use-based charges - Most ISDN service offerings are use-based or have some usage part to the tariff. For fixed-rate services, Data Management is still useful.
- Service requirements (just data, or voice as well) - If voice service is not required, requesting 'data only' may reduce the rental.
- Call Direction selection - It may suit some sites to block incoming calls in the local ISDN switch. This may increase B-channel availability for required outgoing calls and prevent 'nuisance' incoming calls from holding B-channels.
- Fixed-term contracts - Discounts may be available for signing contracts to keep the service installed for a fixed number of years.
- Bulk-order/centralization discounts - Ordering a number of installations at once may reduce the installation cost. As an example, the second Primary Rate installation at a site may be significantly cheaper than the first.
- High-use discounts (maybe use Call Back to centralize billing)
- Request information about 'Frequent Number' discounts, e.g. where a Router only ever calls one or two remote Routers.

3 ISDN compared to other services

In some cases, the decision to use ISDN will be straightforward, in others there will be a

need for complete understanding of the service offerings, tariffs, and the data-profile of the link. If may also be necessary to quantify and prioritize the quality and flexibility of the ISDN service offered over that of analogue, leased-line and other data services. For each type of Wide-Area Network (WAN) link, the **Service Cost**, **Service Aspects** and **Equipment Costs** should be considered.

Note: The cost and nature of the various data services is constantly changing, and any comparisons made in the following examples may be out of date.

- ISDN as an alternative to analogue connections
- ISDN as an alternative to leased-line access.
- ISDN as an alternative to packet data services
- ISDN as backup/failover and bandwidth-on-demand

3.1 *ISDN as an alternative to analogue connections*

In many instances where a remote site requires infrequent access with low volumes of data to a central site e.g. for nightly stock updates, for downloading batched orders etc., use of the Plain Old Telephone System (or POTS) has proved adequate. However, increasing use of more graphically organized information and the need for faster call set-up can stretch an analogue connection to its limit. Even with today's higher speed V.34 modems and advanced compression capabilities, an analogue link is still limited to less than a single ISDN B-channel in terms of throughput - especially when you consider that the same compression techniques can be operated over the ISDN link to gain even more throughput. With ISDN tariffs in many areas getting closer to the analogue equivalents, ISDN is an excellent replacement for these types of application.

3.1.1 Service Cost:

In many countries, ISDN services have been introduced at tariffs which are identical or very close to those of the existing analogue network, but the installation charges and line rental costs of ISDN are usually higher. Since the 'Basic Rate Interface' (BRI) is capable of carrying two 64 Kb/s connections simultaneously, most service providers charge a monthly or quarterly line rental which is twice the cost of a telephone connection - others allow the rental to be based on one or both data channels as required. The following information for each link is needed to make the decision to install ISDN :

- Data Profile : Average number of hours connected per day and average 'idle time' while connected.
- Rental Costs of analogue and ISDN alternatives
- Installation cost
- Tariff structure for analogue and ISDN

For regions that use a **'Fixed'** ISDN tariff (not related to the number of calls or connection time), the ISDN cost can be easily calculated and compared with the analogue service, and the decision to install

ISDN will most likely be made based on the **Service** aspects (e.g. faster data rate).

For ISDN connections that incur a **'Use-Based'** tariff, in addition to the ISDN Service aspects, there is the possibility of substantial savings using Telesaving features which take advantage of the fast call set-up time of ISDN to allow the link to be disconnected (or 'go idle') during periods of inactivity on the link. This aspect of ISDN is sometimes called Time-Cutting.

Note, that if Telesaving features are *not* managed successfully, it is possible for the ISDN connection costs to be many times that cost of an analogue service!

3.1.2 Service Aspects:

The following features of ISDN offer advantages over analogue modem links :

Higher bandwidth. A single ISDN call/connection has a data rate of 64 Kb/s (over a B-Channel) and the BRI service offers the ability to open two 64 Kb/s channels simultaneously to connect to two different remote sites or one site with Bandwidth Aggregation (128 Kb/s). In some regions, the Signaling channel (D-Channel) can be used for additional services/bandwidth (16 Kb/s). If data is being transferred more quickly over ISDN than analogue, responsiveness is improved and the opportunities for Time-Cutting increase. Certain data-hungry application (e.g. video conferencing and application sharing) become possible with ISDN bandwidth.

Lower error rates. Unlike analogue modems that often need to greatly reduce the link speed to cope with line-noise, the ISDN service is a digital transmission network which offers very low bit-error rate and fixed data rates.

Rapid call set-up time. Analogue modems can take 20-30 seconds before data transfer can occur, while ISDN is capable of connecting a call in less than a second for local calls and in 2-3 seconds for national/international calls. This aspect of ISDN has a number of advantages for remote access :

- Allows for Time-Cutting, even when using interactive application (e.g. terminal emulation). Due to the long call set-up time, analogue modems are not well suited to supporting time-cutting. With the opportunities of Telesaving, it is possible to greatly reduce the remote access costs by replacing analogue links with ISDN links.
- Bandwidth-On-Demand and Bandwidth-Aggregation providing near instant response to data load.
- Rapid processing of transactions which increases service availability (e.g. cash-machine transactions) and allows for Over-Booking
- Fast fail-over to alternative central service access points

3.1.3 Equipment Costs:

In 'fan-in' networks (many remote sites using the services of a few central sites), the central site is best served with a LAN-to-WAN router that supports multiple BRI ports or a 'Primary Rate Interface' (PRI) port. A PRI port can offer a better cost/B-

channel for installation and rental with call charges typically being the same for PRI or BRI originated calls (See ISDN Tariffs). The costs of 30 analogue modems would certainly be considerable more expensive than a Primary Rate ISDN router - even when considering the latest Remote Access routers with integral modem support.

Note - in some regions, the NT1 required for attachment is covered by the installation/rental charges, and in others it is the customers' responsibility to provide.

For the remote sites, there are a number of possible solutions. The price of these options is being reduced rapidly due to increased competition :

- ISDN cards (e.g. PC cards)
- ISDN Terminal Adapters (TA)
- ISDN Remote Access LAN-to-WAN routers

DIGITAL ISDN products support the option of a LAN-to-WAN Router for the remote site which has the following advantages:

- Ease of installation (easier than PC cards)
- Support for Centralized management and distribution of software revisions - e.g. new Telesaving features
- Performance (better than Terminal Adapters)
- Integrated Fail-over/Backup features - including fail-over to other non-ISDN services
- Routers are easier to configure for Telesaving than Bridges
- System independence and extendibility - more PCs or Workstations can be added to the remote site without additional ISDN equipment costs.

For Remote sites that already have analogue modems, these could be used as back-up to the ISDN service.

3.2 *ISDN as an alternative to leased-line services*

In applications requiring guaranteed response with high data traffic e.g. manufacturing process control, LAN-to-LAN access etc., a permanent leased line is preferable to an analogue solution. However, the costs associated with a leased line have to be justified given that if the line is under-utilized, the monthly bill still has to be paid. Certainly for applications requiring higher bandwidth than ISDN can offer, e.g. T1/E1 or nx64 Kb/s, a leased-line service is sometimes the only viable alternative although Frame Relay has proved a more cost-effective service in many areas.

3.2.1 Service Cost:

The following information for each link is needed to make the decision :

- Data Profile : Average number of hours connected per day and average 'idle time' while connected.
- Installation costs of lease-line and ISDN alternatives
- Rental Costs of leased-line and ISDN alternatives

- Tariff structure for leased-line and ISDN

In most ISDN regions, ISDN links are more cost effective than the equivalent speed leased-lines for local or intra-region/state connections, but more expensive than leased lines for long-distance - regardless of whether the tariff structure is fixed or use-based. For regions that have fixed tariffs, the calculation should be easy; for use-based tariffs, the comparison will depend on the average daily connect time and the distance of the call.

As an example, in Germany, an ISDN call in the local area (within 20km radius) is priced at 90 seconds per unit (one unit is 0.12DM). Once the distance goes beyond 20km, one unit only pays for 26 seconds and this drops again to 13 seconds outside 50km. The cost (monthly rental) of 64 Kb/s leased-lines in Germany become **gradually** more expensive with distance (e.g. a 64 Kb/s link from Munich to Frankfurt (183km) will cost approximately 1600DM which would only pay for 2.1 hours/working-day ISDN dial connection for the same link (prices from July, 1996 information from Deutsche Telekom Limited). France, Australia and Japan also have tariffs with kilometer-based increased for ISDN connections. In the UK, there are three 'zones', local, regional (up to 35 miles) and national, such that, for the national zone, the ISDN circuit becomes **more attractive with distance** when compared with a leased line!

The Installation charges for lease-lines can be very high, so the length of service contract may have some effect on the calculation. Also, there can be discounts on leased-line contracts for a specified number of years. Another point to note is that higher bandwidth leased-lines tend to be more cost effective (more bits per dollar) as the line speed increases - for example, it may well be more expensive to install/rent/use a Primary Rate ISDN than an equivalent speed leased-line.

For ISDN connections that incur a **'Use-Based'** tariff, there is the possibility of substantial savings using Telesaving features which take advantage of the fast call set-up time of ISDN to allow the link to be disconnected (i.e. 'go idle') during periods of inactivity on the link. This aspect of ISDN is sometimes called Time-Cutting.

If a dial-service is installed and, after a period of use, it is apparent that ISDN dial circuits are not the cheapest option, there may be ISDN-based alternatives that could be used (rather than paying for the ISDN to be disconnected and a standard leased-line to be installed). For example, in Australia, there is a service called ISDN Semi-permanent circuits. This service requires an ISDN call to be connected and not time-cut - the service provider then charges at a rate similar to a leased-line service. Similar services have been tried in Germany but, according to current information, will be phased-out.

3.2.2 Service Aspects:

The following features of ISDN offer advantages over leased-line links :

Flexible bandwidth. It is relatively cheap to have reserve bandwidth via ISDN. For example, if the data requirements vary from 50 Kb/s -128 Kb/s during the day, with an average below 64 Kb/s, it may be appropriate to have a single ISDN BRI interface than two 64 Kb/s leased lines.

Alternatively, ISDN could be used as additional bandwidth to augment a leased-line.

Failover to secondary central sites. Since ISDN is a dial service, a router with an ISDN link can call any other router with an ISDN interface. Thus, unlike a single leased-line, if the primary central-office goes off-line, suitable services may be available elsewhere in the network.

Fan-in application. To support certain network types (e.g. bank cash machines) with a mesh of infrequently-used leased-lines would be considerably more expensive than time-sharing a much lower number of switchable ISDN circuits, e.g. where 20 cash machines share one BRI interface (2 B-channels) at the head office.

Service Integration. Due to the circuit-switched nature of the ISDN service, It is possible to share the ISDN connection with voice, fax and video traffic as well as rate-adapted analogue-sourced data.

3.2.3 Equipment Costs:

In 'fan-in' networks (many remote sites using the services of a few central sites), the central site is best served with a LAN-to-WAN router that supports Multiple BRI or PRI ISDN. A PRI port may offer a better cost/B-channel for installation and rental with call charges typically being the same for PRI or BRI originated calls (See ISDN Tariffs).

Note - in some regions, the NT1 required for attachment is covered by the installation/rental charges, and in others it is the customers responsibility to provide.

When considering ISDN as an alternative to, or replacement for a leased-line, it is likely that the link is intended for a significant amount of use, for example links from branch-offices to central offices. In which case, the LAN-WAN router approach is easily the best choice for the remote site :

- Ease of installation (easier than PC cards)
- Support for Centralized management and distribution of software revisions - e.g. new Telesaving features
- Performance (better than Terminal Adapters)
- Integrated Fail-over/Backup features - including fail-over to other non-ISDN services
- Routers are easier to configure for Telesaving than Bridges
- System independence and extendibility - more PCs or Workstations can be added to the remote site without additional ISDN equipment costs.

3.3 *ISDN as an alternative to Packet Data Services*

Services such as X.25 and Frame Relay can provide higher speed services (up to T1/E1) than analogue or ISDN services without the commitment to a permanent leased line service. They are especially attractive where data traffic patterns are "bursty" in nature and where there is high concentration of fan-in links to a central or regional centre. Since packet data is multiplexed over logical channels within each physical link, then these concentration points need have only

one physical connection compared to multiple connections in a leased line network. X.25 has been traditionally used for guaranteed data delivery using less intelligent terminating equipment e.g. terminals or PADs. It is universally available especially in areas where leased line services are scant and has been popular in the Financial and Travel markets. Frame Relay provides higher access speeds than X.25 and assumes more intelligent terminating equipment (e.g. routers or FRADs).

3.3.1 Service Cost:

The following information for each link is needed to make the decision :

- Data Profile : Average number of hours connected per day and average 'idle time' while connected.
- Installation costs of packet-service and ISDN alternatives
- Rental Costs of packet-service and ISDN alternatives
- Tariff structure for packet-service and ISDN

The installation cost of Frame Relay and X.25 tend to be much higher than ISDN ports. As an example, Pacific Bell charges approximately $1000 for a 128K Frame Relay installation and British Telecom charges 1500 UKpounds for a 64 Kb/s X.25 link.

The monthly rental for these two examples is also much higher than the ISDN BRI services (Pacbell 128K FR - $325/month, BT 64K X.25 - 1320 UKpound/month).

For these two examples of service providers, the usage cost is fixed-rate for the Pacbell Frame Relay, but data is charged by the 'KiloChar' by BT (and is expensive).

If these two service providers are typical, Frame Relay and X.25 have cheaper running costs for long-distance (inter-state/inter-country) traffic, but ISDN does better for local connections. For example, a local (service area tariff) Frame Relay 128 Kb/s link will cost $325/month which equates to 257 hours/month (or 12 hours/working day working with an average of 21 work days per month) of ISDN at 128 Kb/s (both B-channels of a BRI open). The cost of a long-distance (i.e. inter-state) Frame Relay connection is actually cheaper than a local connection at $290/month. This price equates to a 128K ISDN connection over 70 miles (not even inter-state) for only 17 hours/month

British Telecom's X.25 service does not seem to compete with ISDN too well for local connection, but does better for European and International data transfer. A very rough calculation for European X.25 data equates to 6 hours/working-day ISDN connection. Note that the BT charges are only this favorable if you pay for the 'Unlimited Use' option which effectively make the service fixed-rate.

Frame Relay and X.25 services are difficult to compare against ISDN with regards to cost/Bit since the data rate through a Frame Relay and X.25 network is not fixed and the quality of service will experience large fluctuations due to network congestion.

3.3.2 Service Aspects:

Positive and negative aspects of ISDN

compared to packet networks:

***plus* Service Integration**. It is possible to share the ISDN connection with voice, fax and video traffic as well as rate-adapted analogue-sourced data. This advantage may change as Voice over Frame Relay increases.

***minus* Multiplexing**. Packet networks can support simultaneous connections over a 64 Kb/s link. This allows for gradual per virtual circuit throughput degradation. ISDN can multiplex the 64K link by disconnecting from one address and re-connecting to another, but the call-disconnect/reconnect will take at least 3 seconds in which time no data is exchanged which will affect responsiveness of interactive data (e.g. terminal emulation). This may not be a problem for certain applications (e.g. short transaction processing), but the cost of rapid calling on ISDN in use-based tariff regions can be very, very high due to 'Minimum Call Charges'. For these reasons, multiplexing on ISDN may not be cost-effective. An alternative is just to install more ISDN links, for example, a Primary Rate monthly rental in the UK (30 64 Kb/s B-channels) is still less than the rental of one 64 Kb/s X.25 link. Obviously, the usage charge for 30 B-channels will be more than 1 B-channel, but good use of Telesaving techniques may still deliver a monthly bill less than the a single 64 Kb/s X.25 link.

***plus* Constant data-rate**. Unlike packet services, and ISDN connection does not suffer from variable throughput and congestion; if the connection is successful, it should hold at 64 Kb/s. This is obviously a good point for time-critical applications, but it also avoids services becoming gradually slower/unusable.

***plus* Access to packet service via ISDN.** A number of regions already offer access to packet services via the D-channel of ISDN, but access via B-channels is also available. This may offer large installation cost savings and will certainly increases the flexibility and future-proofing of ISDN. Since the data channels of ISDN can carry ANY digital data, any format (X.25/SMDS/Frame Relay/ATM) of packet or cell can be transmitted in its native form.

3.3.3 Equipment Costs:

In 'fan-in' networks (many remote sites using the services of a few central sites), the central site is best served with a LAN-to-WAN router that supports Multiple BRI or a PRI port - typically, PRI offers a better cost/B-channel for installation and rental with call charges being the same for PRI or BRI originated calls (See ISDN Tariffs).

Note - in some regions, the NT1 required for attachment is covered by the installation/rental charges, and in others it is the customers responsibility to provide.

When considering ISDN as an alternative to, or replacement for a packet-service link, it is likely that the link is intended for a significant amount of use, for example links from branch-offices to central offices. In which case, the LAN-WAN router approach is easily the best choice (cheapest/most expandable) for the following reasons :

- Ease of installation (easier than PC cards)
- Support for Centralized management and distribution of software revisions - e.g. new Telesaving features

- Performance (better than Terminal Adapters)
- Integrated Fail-over/Backup features - including fail-over to other non-ISDN services
- Routers are easier to configure for Telesaving than Bridges
- System independence and extendibility - more PCs or Workstations can be added to the remote site without additional ISDN equipment costs.

3.4 *ISDN and Bandwidth on Demand*

Due to its fast call set-up times, ISDN is an ideal service to use when a line is only brought up when there is data to send (Bandwidth on Demand). It is also widely used to provide either a back-up or as additional bandwidth for a leased line. In this case the ISDN link will be brought up if the leased line fails or if a pre-determined bandwidth threshold is exceeded

3.4.1 ISDN as primary with BoD

If ISDN is the only link between a pair of network nodes, Bandwidth on Demand can be used to allocate additional bandwidth as required as shown in Figure 1 If the link between Router A and Router B fails due to one of the Routers failing, the surviving router can connect to a secondary network access router using WAN Reroute. If the router has a serial port as well as ISDN, it is possible to use the serial port for low-speed modem WAN Reroute/Restoral.

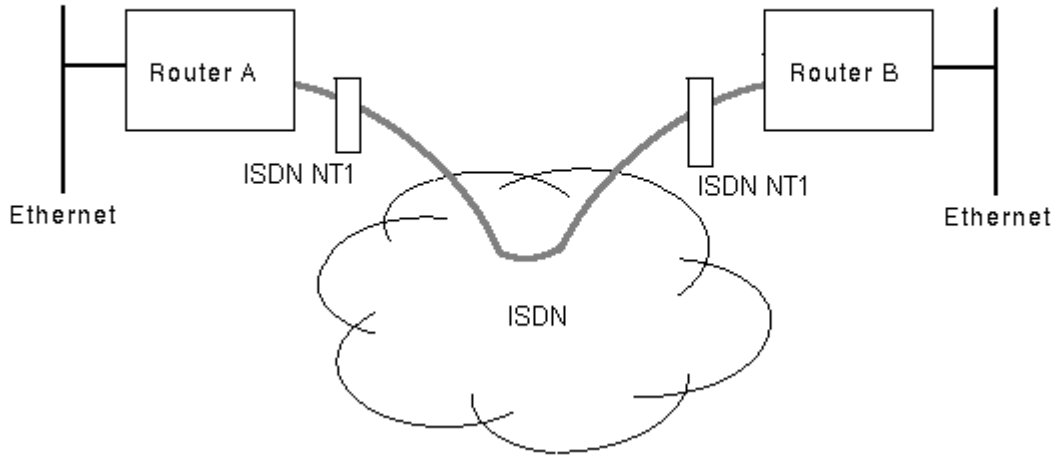

Figure 1: ISDN as BoD

3.4.2 ISDN as secondary bandwidth and backup to a Leased Line.

In this configuration, a higher capacity leased-line is backed-up by a Basic Rate ISDN link. If the Primary link becomes heavily loaded, the ISDN link can be used to add an additional 128K to the available bandwidth as shown in Figure 2. If the Primary link fails, the ISDN link can be used to re-establish connectivity using WAN Reroute/Restoral.

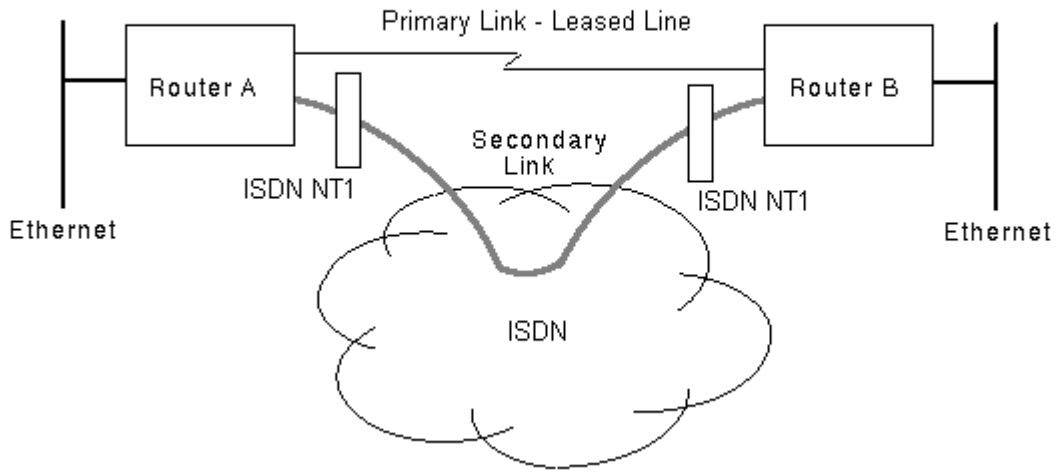

Figure 2: ISDN as Back-up

3.4.3 Service Cost:

Backup/Failover to Leased-Line : A BRI ISDN connection provides 64K to 128K of recovery bandwidth at a very good price - low installation cost, low monthly rental, and, particularly in use-based tariff regions, very low running costs.

Additional bandwidth to supplement a leased-line. Using PPP Multilink and Bandwidth-On-Demand features, 'busy-hour' data can be accommodated by using a number of ISDN dial channels. A study of the data-profile of the 'overflow' traffic is still needed since the cost effectiveness will depend on the hours of connect time and the distance of the connection.

3.4.4 Service Aspects:

ISDN's possible advantage over other supplementary options has already been discussed in the previous sections. On the topic of failover and additional bandwidth, ISDN's feature of rapid call set-up will assist the responsiveness of these two requirements.

3.4.5 Equipment Costs:

In 'fan-in' networks (many remote sites using the services of a few central sites), the

central site is best served with a router that supports Multiple BRI or a PRI port, plus a number of serial ports to support the primary leased-line connections - typically, PRI offers a better cost/B-channel for installation and rental with call charges being the same for PRI or BRI originated calls (See ISDN Tariffs).

Note - in some regions, the NT1 required for attachment is covered by the installation/rental charges, and in others it is the customers responsibility to provide.

For smaller offices with a single leased-line/ISDN port to a larger office, a single ISDN router with 1*LAN, 1*Serial, 1*BRI may be sufficient.

DIGITAL ISDN products include a medium-sized Branch-Office router and a larger Central-Site router that support the following failover/BoD features :

- WAN Restoral - dynamic recovery using a secondary data-link to the same remote router
- WAN reroute - dynamic re-routing to a secondary remote router
- Multilink PPP - leased-line bandwidth can be aggregated with ISDN B-channels.
- Bandwidth On Demand - the ISDN is only used when the primary leased-line link becomes saturated

4 DIGITAL ISDN Products

The DIGITAL RouteAbout product family are ideal for connecting small remote sites into a central site using leased line, frame relay, ISDN or X.25 services. The family consists of Access routers for small to medium sized branch office sites and larger Central routers for the regional or the corporate headquarters site. The small office routers are standalone devices and the larger branch office and central office products can be fully integrated into the DIGITAL DEChub 90, MultiStack and DEChub 900/MultiSwitch solutions. The routers run the DIGITAL Distributed Routing Software and are managed with the DIGITAL clearVISN software suite.

4.1 *RouteAbout Access ISDN*

The RouteAbout Access ISDN has one Ethernet port (UTP) and an ISDN Basic Rate port (U connection in the US; S/T connection outside the US).

It operates as a standalone device and can be connected directly to a user PC or to a collection of PCs in a small office through an Ethernet hub.

It runs a cut-down version of the DIGITAL Distributed Routing Software to provide either TCP/IP, IPX, Appletalk routing and/or bridging over ISDN data links. It is ideal for Telesaving applications such

Bandwidth-on Demand where the ISDN links is only brought up at certain times of the day when there is data to be transmitted or received. It also supports compression, IPX spoofing and multilink PPP and is ideal to small remote offices with 5 to 20 users.

4.2 *RouteAbout Access EI*

The RouteAbout Access EI has one Ethernet port (Thinwire or UTP), an ISDN Basic Rate port (S/T connection) and a serial line which can operate at speeds up to T1/E1 (1.54/2.0 Mb/s).

It operates standalone with a special docking station or can be inserted into the DIGITAL DEChub 90 or DEChub 900 MultiSwitch were the Ethernet connection may be directed to the hub backplane and connect to other devices in the hub such as repeaters, access servers, routers or bridges.

It runs the DIGITAL Distributed Routing Software to provide full function multi-protocol routing and bridging over ISDN, leased line, Frame Relay and X.25 data links. It is ideal for Telesaving applications such as Leased Line failover where the ISDN port can provide a switched back up to either a leased line or Frame Relay connection. It is targeted at larger branch offices supporting from 20-100 users.

4.3 *RouteAbout Central EI*

The RouteAbout Central EI has two Ethernet ports, four (4) T1/E1 serial lines and twelve (12) ISDN Basic Rate Interface S/T interfaces.

It operates standalone with a special docking station or can be inserted into the DIGITAL Multiswitch 900 where the Ethernet connections may be directed to the hub backplane and connect to other devices in the hub such as repeaters, switches, access servers, routers or bridges.

It runs the DIGITAL Distributed Routing Software to provide full function multi-protocol routing and bridging over ISDN, leased line, Frame Relay and X.25 data links.

4.4 *RouteAbout Central EP*

The RouteAbout Central EP has two Ethernet ports, four (4) T1/E1 serial lines and two (2) ISDN Primary Rate Interface S/T interfaces. It includes a Time-of-day clock and compression hardware for implementing Telsaving features.

It operates standalone with a special docking station or can be inserted into the DIGITAL Multiswitch 900 where the Ethernet connections may be directed to the hub backplane and connect to other devices in the hub such as repeaters, switches, access servers, routers or bridges.

It runs the DIGITAL Distributed Routing Software to provide full function multi-protocol routing and bridging over ISDN, leased line, Frame Relay and X.25 data links.

4.5 *Distributed Routing Software*

The DIGITAL Distributed Routing software is the intelligence behind the Telesaving features described in this whitepaper. It runs across all the DIGITAL RouteAbout and DECswitch family of routers and switches. In addition to the Telesaving features, it provides full-function multi-protocol routing and bridging for all the major network protocols including: TCP/IP, DECnet, Novell Netware, Appletalk and OSI. Note that due to memory limitations, not all protocols can be supported on the smaller RouteAbout platforms.

Feature Group	*Supported features*
Bridging	Transparent (802.1d) Bridging
WAN Datalinks	PPP, Multilink PPP, Frame Relay (PVC and SVC), ISDN (BRI and PRI), X.25 (PVC and SVC), V.25bis dial-up, and DTR Dial.
Routing	TCP/IP, Novell IPX, AppleTalk, DECnet Phase IV, and DECnet/OSI
Routing Protocols	OSPF/RIP/EGP/BGP4/PIM, Integrated IS-IS, IPX RIP, and AppleTalk RTMP
Telesaving Features	Packet filtering, Bandwidth reservation, STAC Data Compression, Bandwidth on Demand, WAN Restoral and Reroute, Triggered RIP, IPX Spoofing, NETBIOS/IPX Filtering, Budget Control, Initial Minimum Call Timer, Call Blocking, One-Call Call Back, Frame Relay and X.25 over ISDN, TCP/IP Header compression (Van Jacobson), Telesaving MIB, Dynamic Multilink PPP.
X.25 Features	X.25 LAN/WAN Relay; RFC 877 (IP over X.25), RFC 1356 (IPX over X.25), DECnet/OSI X.25 DLM/DA, X.25 over ISDN B-channel.
Management	Console/TELNET, clearVISN Router Configurator. Monitoring using clearVISN Router Manager. Telesaving Monitoring via Web Browser.
Software Load	Factory loaded in FLASH. Upgradeable via BootP/TFTP

Table 2: Distributed Routing Software Features

5 Configuring and Monitoring Telesaving

5.1 *Configuration and Monitoring using the clearVISN Router Configurator*

The clearVISN Router Configurator tool kit supports configuration and monitoring of the Telesaving features of the RouteAbout family. This graphical tool kit greatly simplifies configuration and monitoring. A GUI tool is available to configure the Telesaving feature and a standard web browser can be used to monitor how well the Telesaving features are working on a configured router. For example, an ISDN budget can be configured for a router and then a web browser used to monitor how the budget is being spent. The Telesaving SNMP MIB supports 120 Telesaving information items (SNMP objects) to allow other Telesaving features, such as Compression, to be monitored via a web browser, and this provides a useful starting point when fine-tuning Telesaving.

5.2 *DIGITAL Trace Facility - DTF*

If ISDN call charges are running ahead of an expected budget, and the Telesaving MIB does not provide sufficient detail to determine the cause, the DTF graphical trace tool can be used to trace traffic on an ISDN link. DTF is useful when investigating 'noise' on an ISDN link that is causing frequent calls to be placed or preventing calls from being idled-out (disconnected).

5.3 *ISDN Bills*

An itemised ISDN bill can be useful in finding cost saving opportunities and checking that the Budget control are working correctly. For example, very short duration calls are generally to be avoided since they can reflect configuration problems, such as the poor setting of the Initial Minimum Call Timer feature. If an Initial Minimum call charge is imposed by the service provider, it can prove to be very expensive to make back-to-back short-duration calls.

The bill can also be used to see what numbers are called and to make a judgment as to which ISDN numbers should be included in a 'Frequent Numbers' list for which discounts are offered by the service provider.

At the very least, the bill should be compared with the record provided by the Budget Control features to see that the budget used is in agreement with the amount charged by the service provider.

6 ISDN Background Information

6.1 *ISDN History*

Integrated **S**ervices **D**igital **N**etwork (**ISDN**) has been around since the mid 1980s and was designed as a means to deliver a digital service over existing twisted-pair wiring that could carry voice/fax/video (analogue data) and computer data over a single interface. ISDN was originally developed under the auspices of the Comité Consultatif International Télégraphique et Téléphonique (or CCITT), now known as the International Telecommunications Union (ITU). Although the specifications have been available for years, only in the last 2-3 years has service

availability and affordable tariffs made it an attractive offering for consumers to use and for equipment vendors to build ISDN products in volume.

Two types of interface are defined for ISDN - Basic Rate Interface and Primary Rate Interface :

ISDN's **Basic Rate Interface (BRI)** digital technology provides three communication paths or channels, over the same copper wire connector that provides integrated services.

The ISDN BRI, also known as 2B+D. This arrangement provides two "B" (**B**earer channels) and one "D" (**D**elta) channel. Each of the "B" channels can carry voice/fax/video/circuit-switched-data/packet-switched-data at up to 64 Kb/s. The D-channel carries signaling information between the central office and the subscriber's ISDN equipment and may also be used to carry packet switched data at up to 16 Kb/s.

ISDN was designed to integrate with traditional telephone service, so that customers who subscribe to ISDN services can make voice-calls to, and receive voice-calls from, customers who subscribe to traditional telephone service.

ISDN offers the following advantages over using telephone connections for voice and data :

- Two simultaneous connection (voice or data) over the B-channels and perhaps further logical connection using the packet switched interface of the D-Channel. - all with one physical interface.
- Voice, circuit-switched data and packet data services
- New bandwidth-hungry applications to the home and office
- Noise-free operation over existing lines
- Rapid call connections (very useful for data equipment)

ISDN's **Primary Rate Interface (PRI)** comes in two basic size :

D-Channel (64 Kb/s) + 23 B-Channels (64 Kb/s) - US/Japan

D-Channel (64 Kb/s) + 30 B-Channels (64 Kb/s) - Europe/Australia

PRI ISDN offers the same features as BRI, but on a larger scale. PRI can be a more cost-effective way for a central office to support a number of remote BRI users. Large office ISDN PABX systems would use PRI interfaces, for example.

6.2 *ISDN Services*

The introduction of ISDN services round the world is going through a high-growth period currently. The main areas of activity are :

- Europe
- USA
- Japan
- Australia

ISDN providers can offer a bewildering array of service types (e.g. Deutsche Telecom, Germany), but the data services

can be broadly described as :

- Basic Rate Interface (BRI) (1 D-Channel (16 Kb/s), 2 B-Channels (64 Kb/s))
- Primary Rate Interface (1 D-channels (64 Kb/s), 30 or 23 B-Channels (64 Kb/s))
- Partial BRI and PRI (optional D-channel and variable number of B-channels)
- D-Channel access to packet networks (e.g. X.25)
- B-Channel access to packet networks
- Analogue support built in to the NT1 (phone jack - e.g. France)
- Semi-permanent connections

The service offering are more complex when limitation on supported services (e.g. voice and data), facilities (e.g. Calling Line Identifier) and call direction (e.g. outgoing calls only) are added into the price book. There are also savings to be made for installing a large number of ports, for example currently (July 1996) British Telecom charge 99 UKpounds/channels for PRI channels for the first 30 and then the cost drops to 58 UKpounds/channel for subsequent channels.

6.3 *ISDN Tariffs*

As well as installation and rental charges, many regions apply a tariff for seconds or minutes of connection time. In some regions, this 'use-based' tariff is only applied for connections made to sites outside the local area. Knowledge of the tariffs for local, national and international connections should be obtained from the service providers and this will enable Telesaving features to be used optimally:

- Information on tariffs should be collected for all local and remote service providers since it may be cheaper for location A to call location B than for B to call A (depending on base tariffs, exchange rates, time-of-day/week).
- Tariffs for BRI and PRI originated calls are usually the same, but monthly rental charges and installation costs for PRI can be cheaper per B-channels.
- Tariff patterns will affect the way Telesaving features are used.
- Service Tariffs can be complex.
- 'Break-even point' graphs comparing the cost of ISDN with other services will help set the target for the Telesaving features.
- Semi-permanent ISDN connections can offer a 'next-step' if usage increases.
- Connection to packet/frame networks may be cheaper via ISDN.
- Bulk Orders and Bulk Use may offer savings

DIGITAL has compiled a table of the latest tariff information it has obtained from ISDN service providers. While not guaranteeing its accuracy, it provides a useful comparison

and planning tool. Users should always contact the service provider directly for the latest tariff information which are subject to change. To view this table, please consult the HTML version of this whitepaper at: www.networks.digital.com.

6.4 *ISDN Glossary*

Call type: ISDN supports three types of calls: circuit switched voice/fax/video, circuit switched data and packet switched data.

Circuit Switched Data: A connection, or call, between two devices (e.g. routers) which is has a speed of 64 Kb/s.

B or D Packet data: The exact nature of the service will depend on how integrated packet services are with the ISDN network. Most providers will offer X.25 access via D and B channels. Packet data on the B-channel will use the LAPB datalink used in X.25 networks, packet data on the D-channel will use LAPD - the ISDN defined datalink protocol.

NT1: The NT1 (Network Termination 1*)* In Europe, the service provider is required to install the NT1 to which the customers' ISDN equipment attaches. The US, the customer may select to provide the NT1 independently.

Semi-permanent Circuit: In some countries/states, an arrange can be made to be charged at rates similar to that of leased-lines for ISDN connections that are made and then left connected. Typically, this is only cheaper than leased-lines over short distances.

Time-Cutting: Disconnecting dial circuits during idle periods and reconnecting as data arrives for forwarding (made possible by the rapid call establishment possible with ISDN).

Bandwidth On Demand: Adding Dial-circuit (e.g. ISDN) bandwidth in the following situations:

- When there is no active B-channel to the site for which data received by the router is to be forwarded to (initial channel).
- When the active bandwidth is over-loaded and additional bandwidth can be added using Bandwidth Aggregation.
- For WAN Reroute/Restoral when a Primary link has failed.

In many tariff regions, ISDN provides a cost effect way of building virtual bandwidth into the network. This bandwidth can be used and released as needed to cope with various tariff loads, or to recover from failed connections or services. Once the added bandwidth is no longer required, the ISDN call is cleared.

Bandwidth Aggregation: Related to Bandwidth on Demand - If extra bandwidth is required between a pair of routers, and ISDN B-channel can be aggregated (or augmented) with another channel (e.g. leased-line) using PPP Multilink protocol.

Overbooking: Due to the rapid call establishments possible with ISDN, B-channels can be shared between a number of target sites.

Minimum Call Charge: Most ISDN tariffs apply a fixed charge per connection. This charge will be applied even for very short

calls. For example, in the UK, each connection is charged a minimum of 4.2 pence per call.

Tariff Patterns: The call charges for ISDN varies with Time-Of-Year and distance. Most regions have at least three tariff 'zones' during the period of a week during which the charging unit (say, number of seconds per currency unit) varies from zone to zone.

6.5 *ISDN Information Sources*

The following world wide web sites contain a wealth of information pertaining to ISDN technology, availability, tariffs and products.

Dan Kegel's ISDN Page
(http://www.alumni.caltech.edu/~dank/isdn/)

This is a good clearing house for all ISDN questions, latest news and debates. It is mainly US focused but does contain a wealth of ISDN information and pointers to other sources of information

Bellcore ISDN Home Page
(http://www.bellcore.com/ISDN/index.html)

Excellent for Technical Information on ISDN given that a lot of the original design for ISDN was done at the Bell Labs. Also contains the home page for the US National ISDN Council.

The North American ISDN Users' Forum Home Page
(http://www.niuf.nist.gov/misc/niuf.html)

Good for US ISDN users to find out the latest information on ISDN provided by the RBOCs.

EIUF: European ISDN User Forum
(http://www2.echo.lu/eiuf/en/eiuf.html)

Good for European ISDN users to find out the latest information on ISDN provided by the European Telecommunications Service Providers.

What's Hot - ISDN
(http://www.data.com/whats_hot/isdn.html)

An interesting collection of articles on ISDN from Data Communications magazine.

7 About the authors

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For more information about DIGITAL's Network products please visit our World Wide Web site at:

http://www.networks.digital.com/